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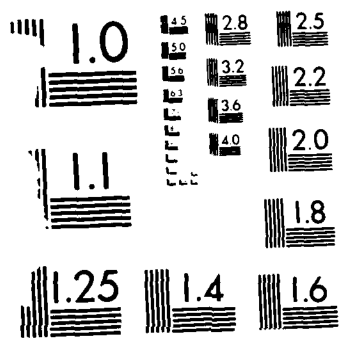

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Dense Plasma Focus, Hypocycloidal-Pinch Plasma(HCP), Blue-Green Laser, LD490 dye, Spectrum conversion of HCP pumping light, Coumarin 503.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A high power blue-green laser was pumped with an array of the dense plasma focus (DPF). As the result of optimizing the operating conditions of the dense plasma focus and laser system, the maximum untuned laser output exceeded 2.1mJ which corresponds to the energy density 3J/cm^3 which is much higher than the

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) typical flashlamp dye laser. The optimum operating conditions of the DPF device and laser system were argon pressure 0.3 torr, dye concentration 6×10^{-4} mol/liter and 10% output transmission mirror.

In order to enhance the efficiency of a blue-green laser through spectrum conversion of the pumping light, a converter dye, BBQ, was mixed in the laser dye solutions. The laser was pumped with the hypocyloidal-pinch plasma (HCP) radiation source. The maximum increase of laser output at the dye mixture of LD490+BBQ or coumarin 503+BBQ was about 80%. The enhancement is mainly due to the abundance of near uv in the pumping source, the fairly good match of the fluorescence band of converter dye with the absorption band of the laser dye, and a small overlap of fluorescence band of laser dyes with triplet- triplet absorption band of converter dye.

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A PLASMA ULTRAVIOLET SOURCE FOR SHORT WAVELENGTH LASERS

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A PLASMA ULTRAVIOLET LIGHT SOURCE FOR SHORT WAVELENGTH LASERS

ABSTRACT

A high power blue-green laser was pumped with an array of the dense plasma focus (DPF). As the result of optimizing the operating conditions of the dense plasma focus and laser system, the maximum untuned laser output exceeded 2.1mJ corresponding to the energy density 3J/cu cm ~~3J/cm^3~~ which is much higher than the typical flashlamp dye laser. The optimum operating conditions of the DPF device and laser system were argon pressure 0.3 torr, dye concentration 6×10^{-4} mol/liter and 10% output transmission mirror.

In order to enhance the efficiency of a blue-green laser through spectrum conversion of the pumping light, a converter dye, BBQ, was mixed in the laser dye solutions. The laser was pumped with the hypocyloidal-pinch plasma (HCP) radiation source. The maximum increase of laser output at the dye mixture of LD490+BBQ or coumarin 503+BBQ was about 80%. The enhancement is mainly due to the abundance of near uv in the pumping source, the fairly good match of the fluorescence band of converter dye with the absorption band of the laser dye, and a small overlap of fluorescence band of laser dyes with triplet- triplet absorption band of converter dye.

I. INTRODUCTION

Importance of tunable ultraviolet lasers for photochemical research and applications have led to several methods of producing high power uv lasers below $\lambda = 350$ nm. Frequency doubled or tripled high power lasers such as ion, ruby, Nd^{3+}, and visible dye lasers as well as short wavelength excimer lasers have been employed for pumping uv dye lasers. However, these pump sources are complex and expensive laser systems themselves. Consequently, their applications are limited. Therefore, availability of inexpensive flashlamp-pumped high power dye lasers is desirable for the uv range. The flashlamp pumped uv dye lasers are currently available only for wavelength above 330nm and their output energy (< 1J) are limited. This is mainly due to the lack of uv emission from the flashlamps used as the pump source. Efforts to improve the flashlamp-emission efficiency in the uv range have thus far met with limited successes indicating that the radically different and new light sources are required. Such non-repetitive sources as exploding wires or foils which have been studied as intense uv sources for an iodine laser are extreme examples (Ref. 1). Other examples are use of dense plasma sources as investigated in the USSR laboratories for high power laser pumping (Ref. 2, 3, 4). They produced dense plasmas by high current discharges but in a different regime than that of the thermonuclear fusion device (or plasma pinch devices). They report the efficiency of over 70% in terms of the total radiated energy and over 1 kJ of a gas laser output production in 0.251 to 1.04μm.

Recently in the USA, dense plasma focuses produced in hypocycloidal pinch array have been successfully employed for various high power laser pumping (Ref. 5), especially, dye laser pumping at our laboratory (Ref. 6) and at

University of Illinois (Ref. 7). Also there has been preliminary attempt of using a coaxial-gun type plasma focus device for dye laser pumping (Ref. 8). However, the optical coupling and operational conditions of the plasma focus-laser system have not been optimized in this preliminary test and further investigation is necessary to evaluate its potential as a high-power uv laser system.

In order to evaluate the dense plasma focus device (DPF) as an intense uv source, the dense plasma focus device has been modified to realize high optical efficiency for the plasma laser system as shown in figure 1. The modifications of the DPF are: (1) Use of an external magnetic field for plasma stabilization and increase of the linear dimension of the plasma column. The term plasma focus may be inadequate after this modification, since the plasma source is expected to have the shape of a thin elongated rod (2mm dia. x 40mm long) (Ref. 9). (2) Use of high-Z doping such as Ar and Xe which will result in a radatively-cooled high-density ($n_e \sim 10^{24} m^{-3}$) plasma at relatively low temperature ($10^4 \sim 10^5$K) compared with the thermonuclear-pinch plasma produced with pure deuterium ($T_e \sim 1$KeV). (3) Use of an elliptical cylinder mirror (uv reflectivity enhanced) for optical coupling (see Fig. 1) to ensure the optimum coupling coefficient between the source and the laser located on the focal lines of the elliptical cylinder. Details are discussed in Chapter II.

For the enhancement of the blue-green laser system efficiency, the use of converter dyes in the HCP/laser system was also investigated. Details are discussed in chapter III.

II. High power blue green laser by the dense plasma focus

A high power blue-green laser has been pumped with the dense plasma focus device similar to Ref. 1. As shown in figure 1, new features include magnetic stabilization of the plasma and optical coupling with an elliptical cylinder focussing mirror along Z axis and the laser gain medium at anothe foci. The device was operated at 18kV (or 7.8kJ) with fill gas of 0.3 Torr (80% deuterium and 20% argon) produces 2.1mJ laser output corresponding to the energy density 3J/liter which is much higher than the typical flashlamp pumped dye laser.

In order to determine the optimum conditions of pumping blue-green laser and near uv laser, the emission characteristics (200-400nm), the current sheet dynamics, the pressure, and input energy dependence of the laser output were measured. Figure 2 shows a block diagram of experimental set-up. Figure 3 shows average speed of current sheet viewed from the side of electrodes as a function of argon fill pressure. Experimental results indicate that the velocity of current sheet is proportional to $P^{-.46}$ where P is fill gas pressure. The velocity of current sheet follows the snow plow model ($v \sim P^{-0.5}$) as we expected. Figure 3 shows streak photographs of plasma focus formation taken from a side view (a) and top view (b). The top view indicates that the size of plasma focus has a diameter of 3mm and lasts for 0.6us. Figure 4a shows side views of streak photograph of plasma focus with the operating conditions of 0.3 torr agron gas, B=0 and B=60 gauss. Figure 4b also shows side views of streak photogrpah with an operating condition of 0.5 torr argon, B=0 and B=60 gauss. Experimental results definitely indicates that the plasma focus lasts longer with external magnetic field B and is more intense as expected. Figure 5 also shows the side-on streak photograph of plasma focus formation as a function of the combined argon and deuterium gas at 1 torr. Figure 6 shows typical output voltage (top), pumping light (middle) and laser output energy (bottom) oscillograms. In order to determine the optimum operating conditions of the DPF device for pumping blue-green laser (LD490 dye), laser output energy have been measured as a function of argon fill gas pressure (Fig. 7), dye concentration (Fig. 8), transmission of output laser mirror (Fig. 9). As the result of optimization, the maximum untuned laser output exceeded 2.1mJ when measured with an energy meter. The optimum operating conditions of the DPF device and laser system were argon gas pressure 0.3 torr, dye concentration 6 x 10^{-4} mol/liter and 10% output transmission mirror. the details of experimental results were reported at the 1985 Conference of International IEEE Plasa Science (IEEE85CH-2199-8).

For pumping near uv dye laser (LD390 Exciton dye), the emission spectra of the DPF pumping light were also measured as a function of argon/deuterium fill gas pressure. As shown in figure 10 and 11, the peak intensity of the pumping light at the optimum fill pressure was 5.5 times more intense than that at other pressure. This implies that the plasma focus was well formed with the fill pressure of 10% argon and 90% deuterium. One of the experimental difficulties we have at present time is that the insulator between the electrodes in the DPF device frequently is broken during the formation of plasma focus.

III. ENHANCEMENT OF BLUE-GREEN LASER EFFICENCY BY A SPECTRUM CONVERTER*

In order to achieve the more efficient utilization of the near uv-abundant HCP light source for pumping dye lasers, the laser dye mixture method was used. Various concentration of laser dye mixture LD490+BBQ in ethanol and coumarin

503+BBQ in p-dioxane were employed. Description of the HCP plasma source is reported elsewhere. As shown in figure 1, the converter dye BBQ absorbs light in the region 286-333nm of the HCP pumping source where the laser dye LD490 or coumarin 503 absorbs little. On the other hand the converter dye BBQ fluoresces near 380nm which lies in the absorption band 360-416nm of the laser dye LD490 or coumarin 503. The irradiance of the pumping light which is calibrated with a standard W-Halogen source shows a maximum at 300nm in the converter dye absorption band. The intensity at this peak is as six times high as that at 390nm. Thus, as the concentration of converter dye BBQ increases in dye mixture, the fluorescence light near 380nm increases and is absorbed by laser dye LD490 or coumarin 503. An enhancement of laser output is expected as the concentration increases. However, there is a small overlap of fluorescence band of laser dye and triplet absorption band (λ_C=530nm) of converter dye (Ref.9). Consequently the enhancement of laser output is affected at higher concentration.

EXPERIMENTAL RESULTS AND DISCUSSION

A small HCP, which was designed for laser pumping source, was used under the optimum condition of argon fill gas pressure of 1 Torr and an applied energy of 0.9kJ stored at 30kV. Figure 13 and 14 show laser output of LD490 dye and coumarin 503 dye as function of BBQ concentration. The laser output increases as the BBQ concentration increases until it reaches 5×10^{-6}mol/liter where the energy enhancement is 80%. This increase is expected by the converter effect mentioned earlier. Figure 13 and 14 also show there are smaller enhancement for the concentrations of laser dye less than optimum (lower curves). For the smaller converter dye BBQ concentration, the optimum concentration of the converter dye is also small. However, if BBQ concentration with 4×10^{-4} mol/liter of LD490 is more than 10^{-5} mol/liter, then the laser energy decreases as BBQ concentration increases. This may be due to the increased triplet-triplet absorption by BBQ of the fluorescence of the laser dye. Similar results are obtained with the dye mixture of 8×10^{-5} mol/liter coumarin 503 and 4×10^{-6} mol/liter BBQ which are shown in figure 14. The results generally agree with the expectation from a spectrum converter theory but the effect of the radiationless energy transfer (Ref. 10) in the dye mixture will be investigated in future. Details was reported in 1985 AIP Proceeding of 1985 International Laser Science Conference.

IV. Summary and Conclusion

A high power blue-green laser has been pumped with a dense plasma focus device. The maximum untuned laser output exceeded 2.1mJ which corresponds to the energy density $3 J/cm^3$. For future work spectrum will be varied to match the most efficient pumping of near uv dye laser (LD390, BBQ and PTP dye). Measurement of uv spectrum of the magnetically stabilized plasma focus will be continued.

Using the dye mixture of LD490+BBQ or coumarin 503+BBQ, the efficiency of a blue-green laser with the HCP pumping source is increased by about 80%. The resuslt indicates that the energy transfer method can be applied to pumping not only blue-green dye laser but also uv dye laser as well. For future work the uv enhancement of the HCP pumping light in the region of 200-300nm will be continued as a function of fill gas pressure and the concentration of XeCl in argon.

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EXPERIMENTAL SETUP

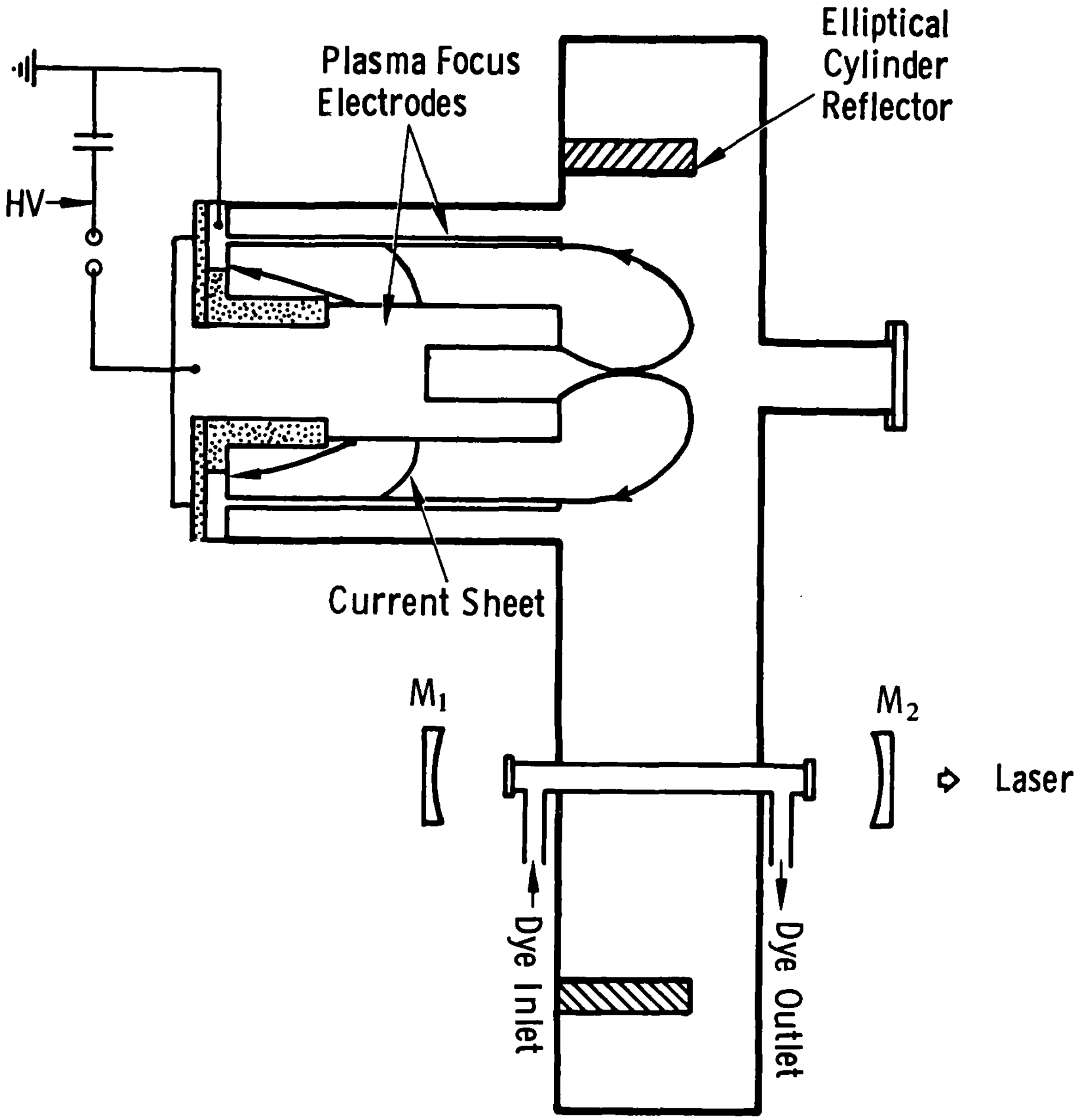


Fig. 1. Experimental set-up of the dense plasma focus and dye laser system.

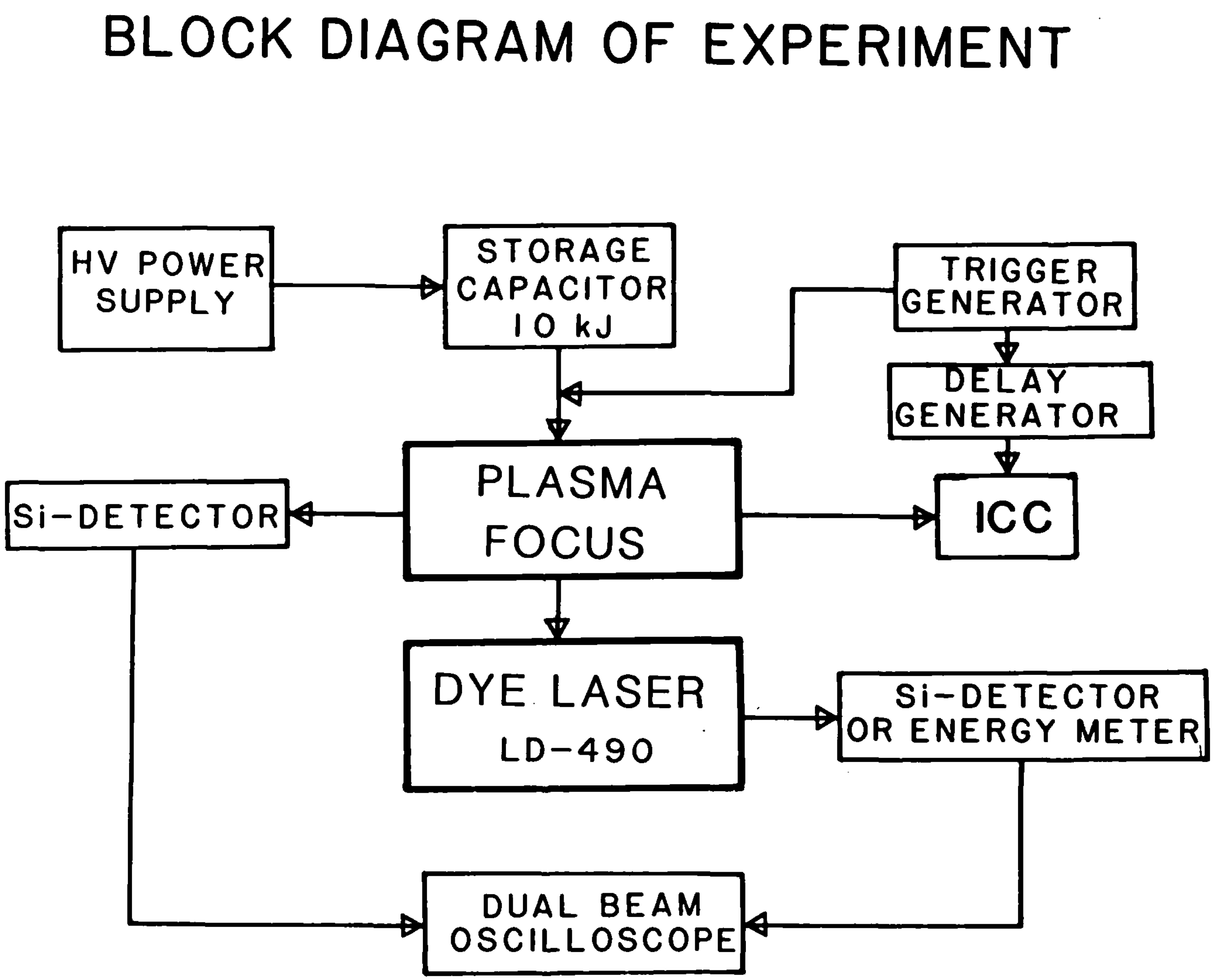


Fig. 2. Block diagram of experiment for monitoring laser signal, current sheath and formation of plasma focus.

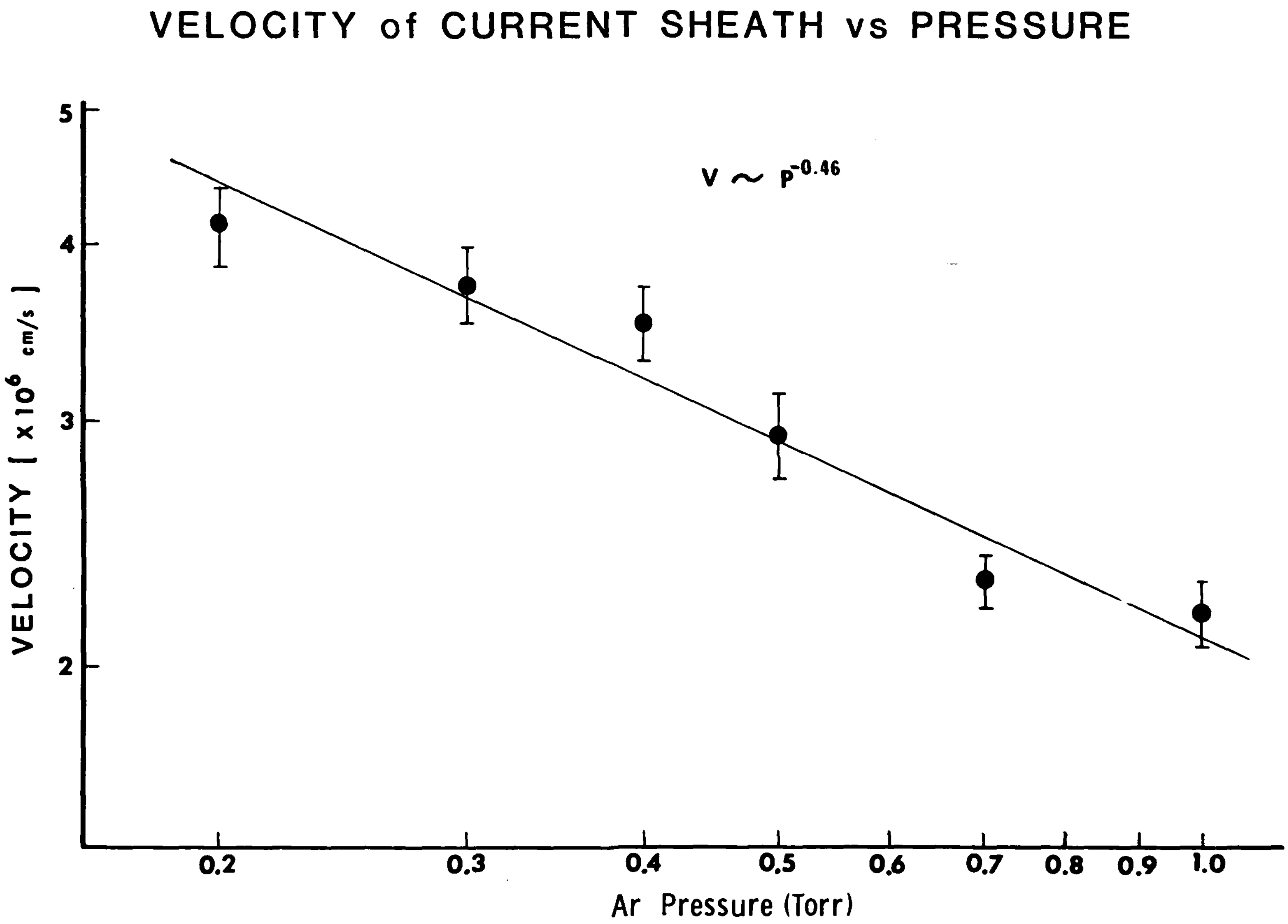
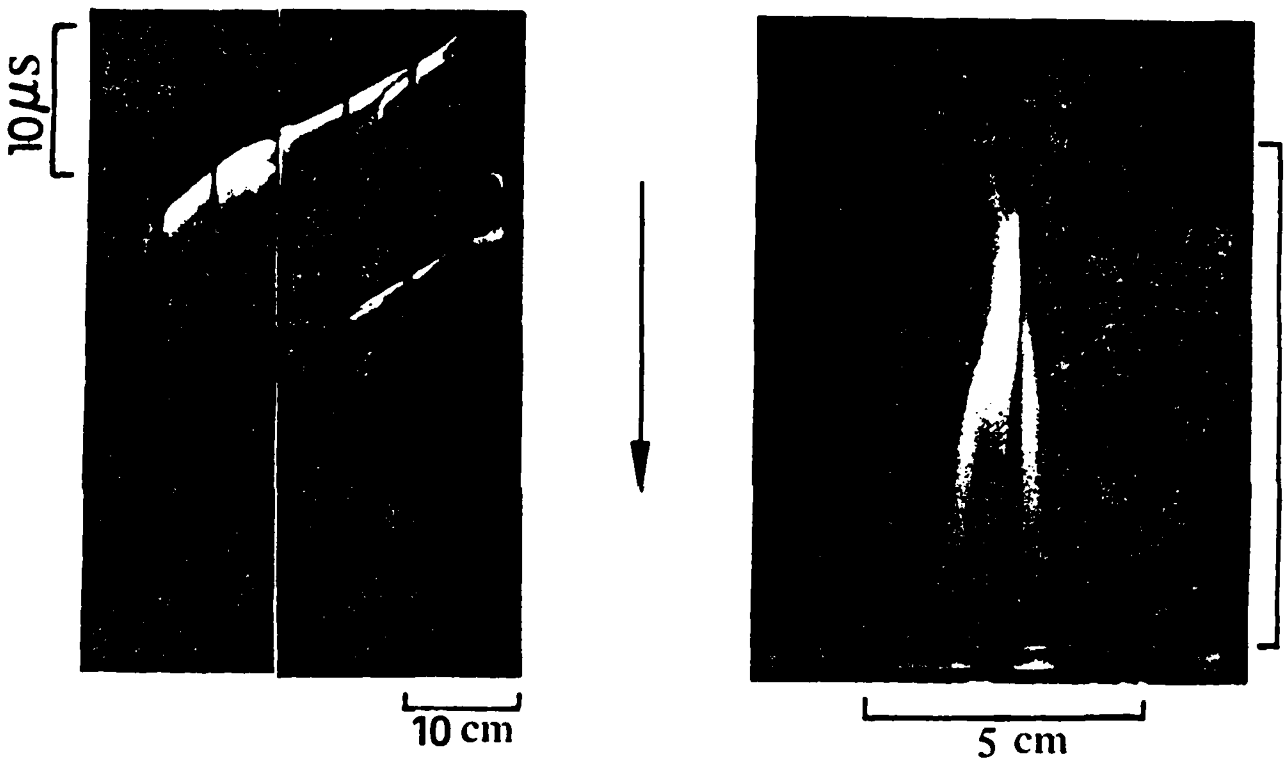


Fig. 3. Average speed of current sheet of the plasma pumping source as a function of argon fill gas pressure.

STREAK PHOTOGRAPH



0.3 Torr Ar + 0.7 Torr D_2

Fig. 4. Streak photograph of plasma focus discharge with fill gas of 0.3 torr or argon and 0.7 torr of deuterium.

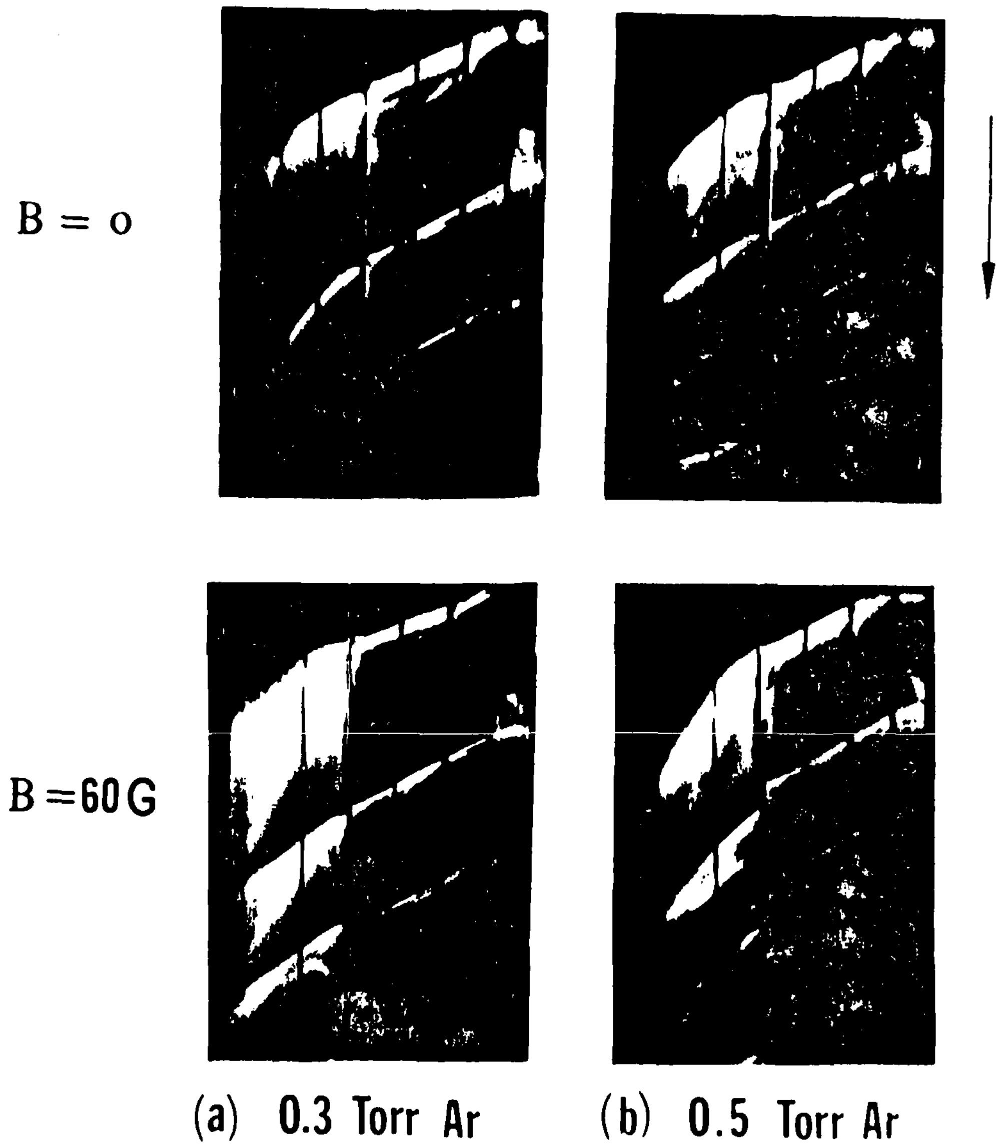


Fig. 5. Side view of streak photograph of plasma focus discharge: B=0 case (top) and B=60 gauss case (bottom).

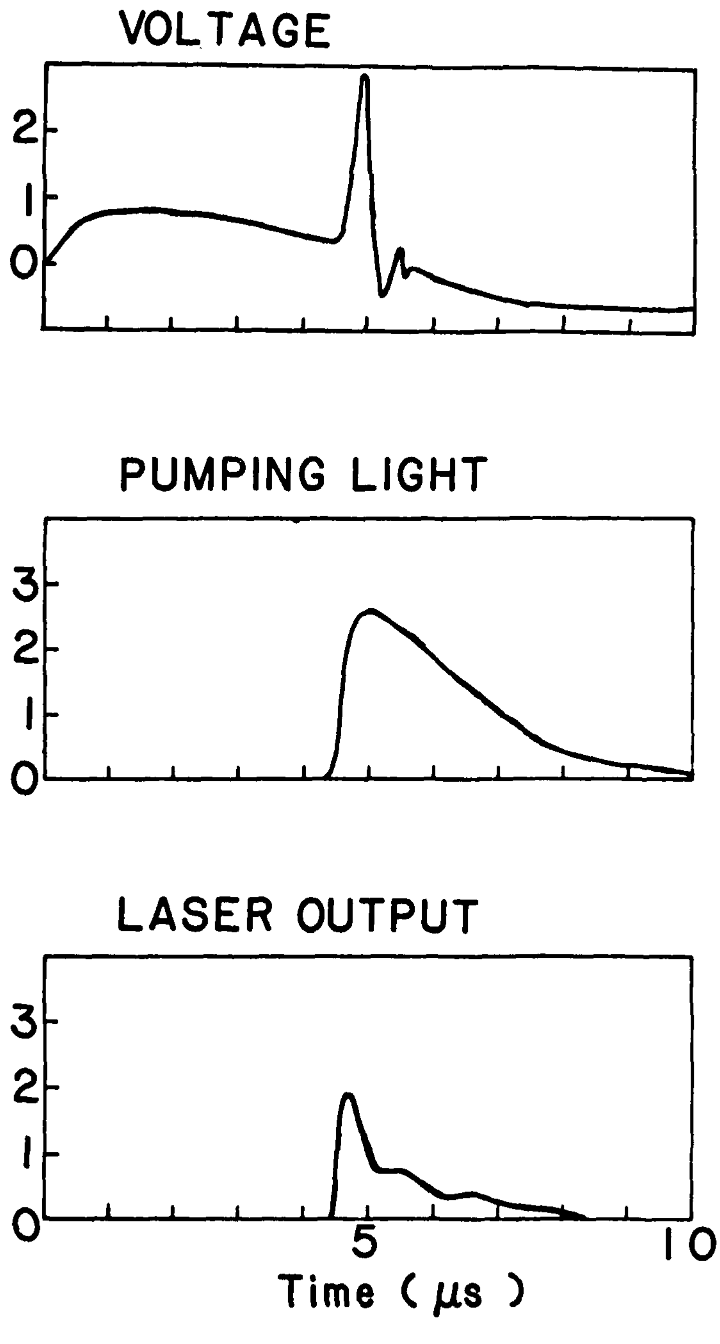


Fig. 6. Typical voltage (top), pumping light (middle) and laser output energy (bottom) oscillogram. Sweeping speed 1 μs/div.

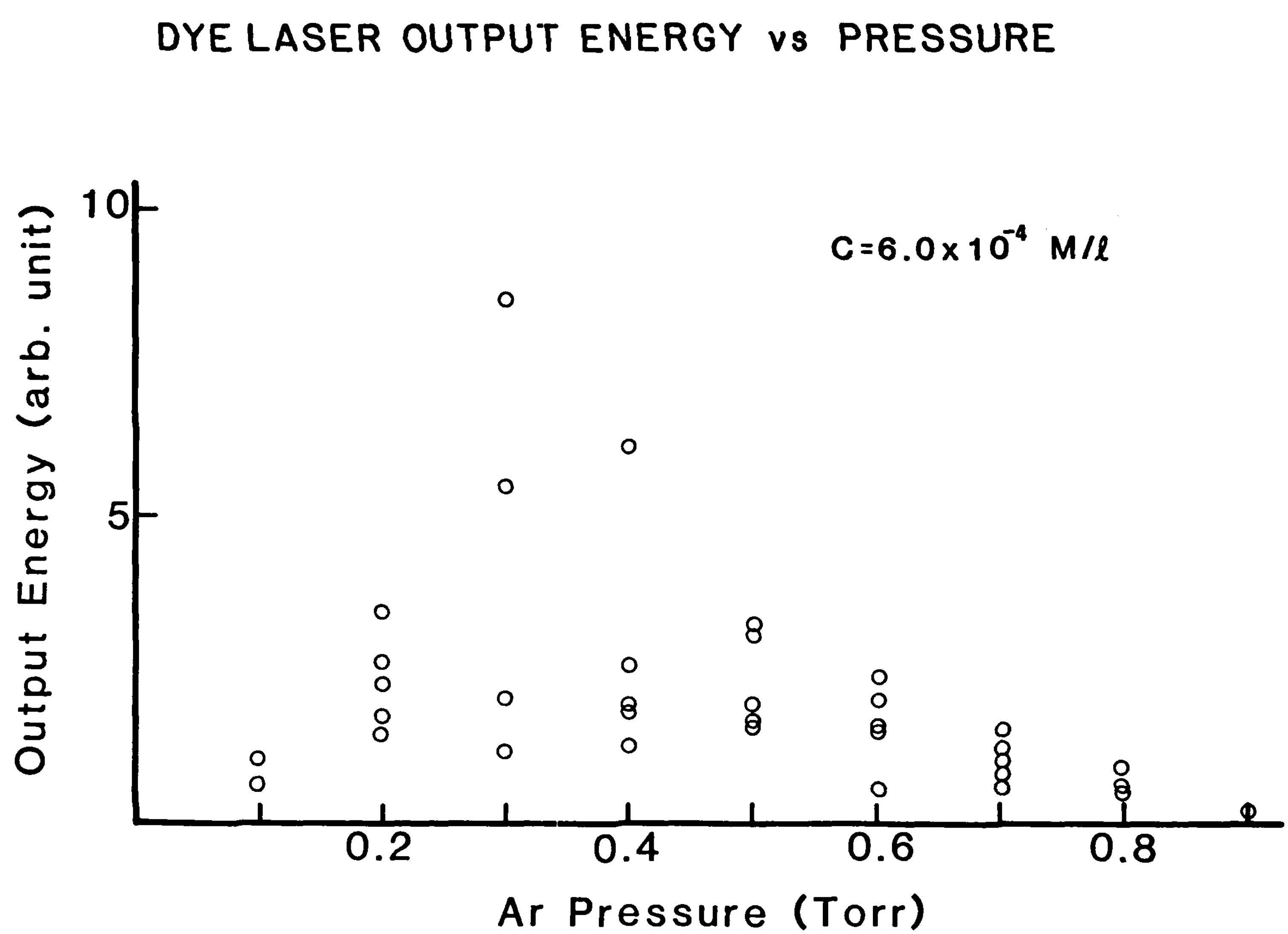


Fig. 7. Dye (LD490) laser output energy as a function of argon fill gas pressure.

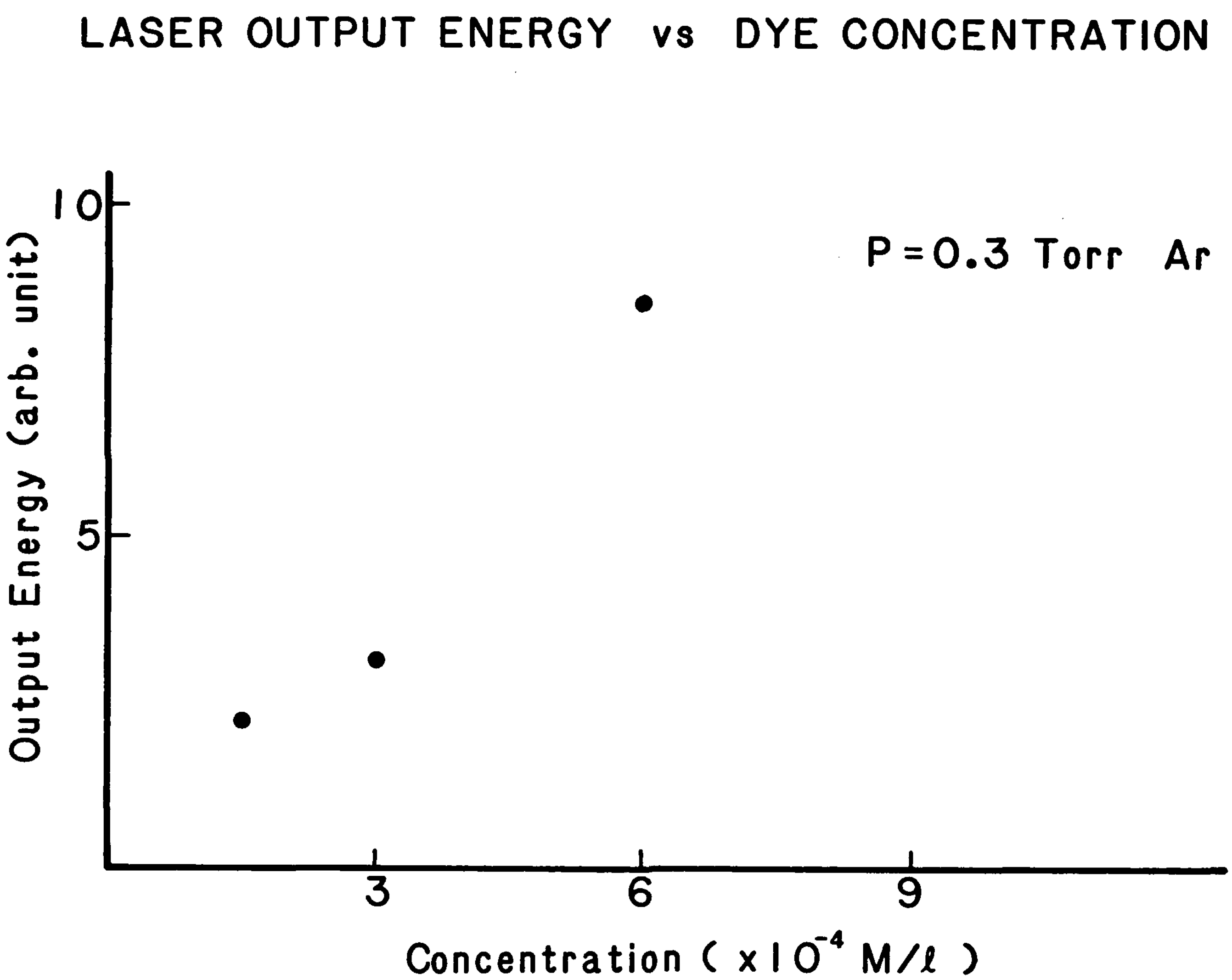


Fig. 8. Dye (LD490) laser output energy as a function of dye concentration.

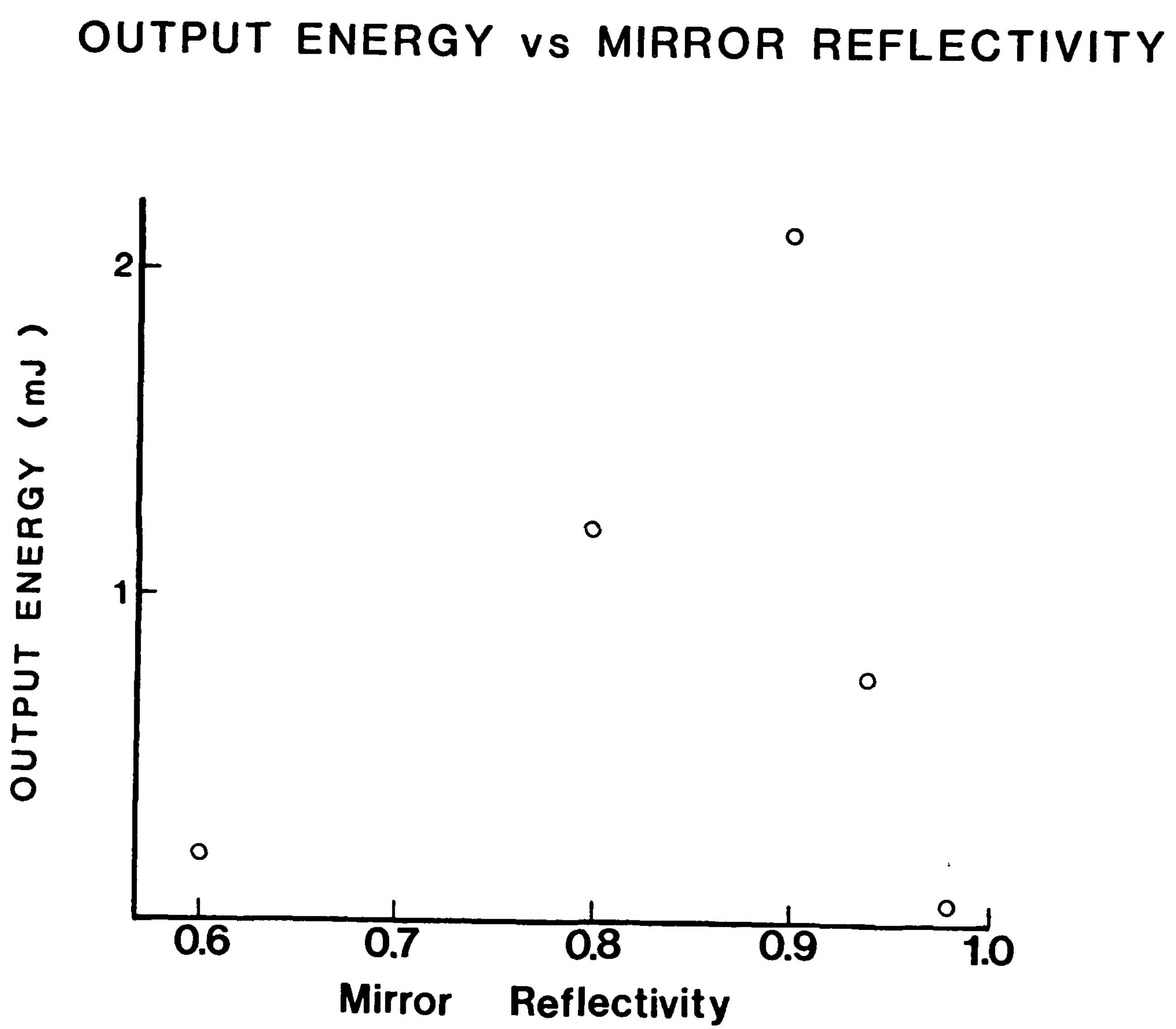


Fig. 9. Laser output energy as a function of laser mirror reflectivity.

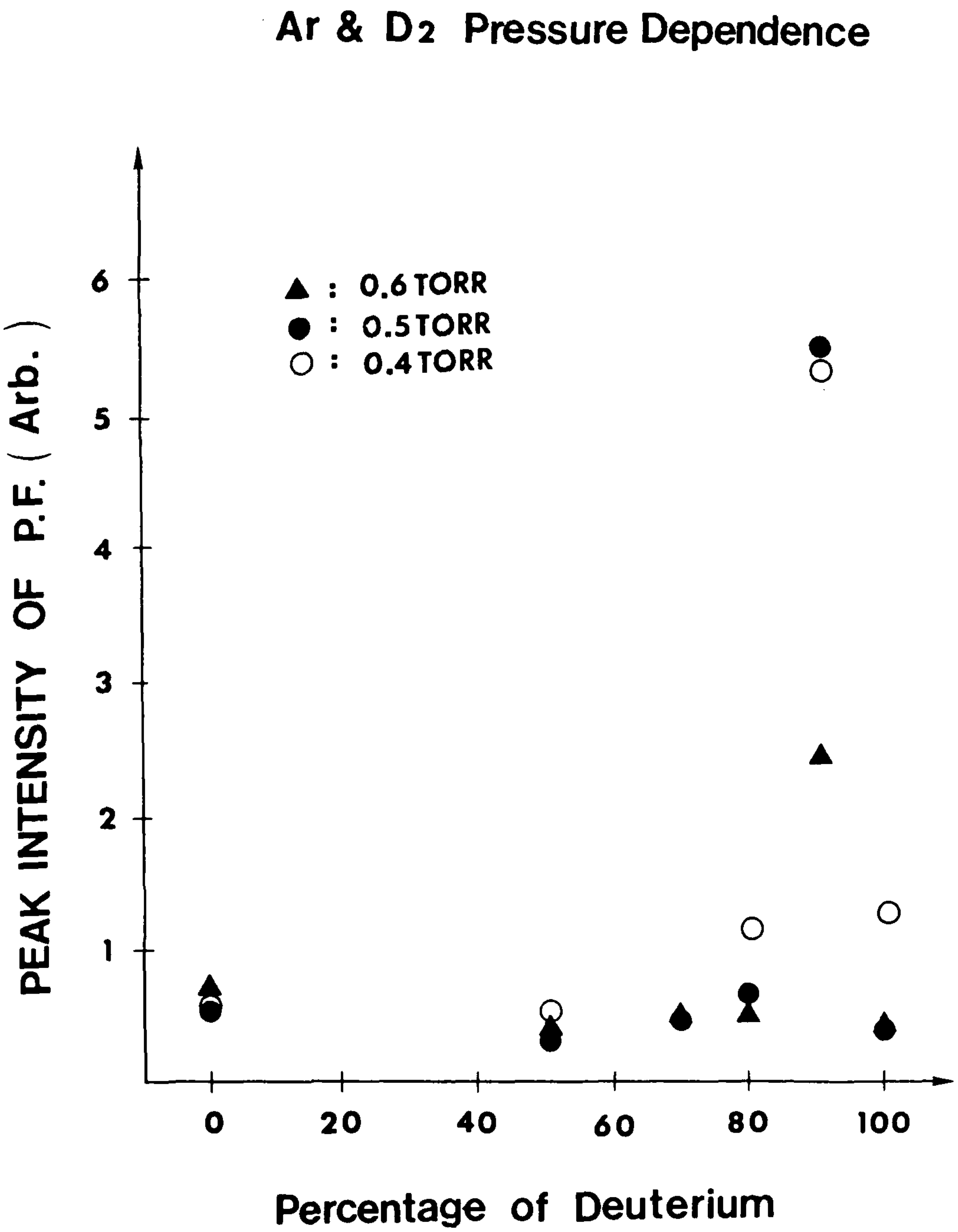


Fig. 10 Peak intensity of the dense plasma focus (DPF) as a function of deuterium fill gas at a fixed total pressure of argon and deuterium gas.

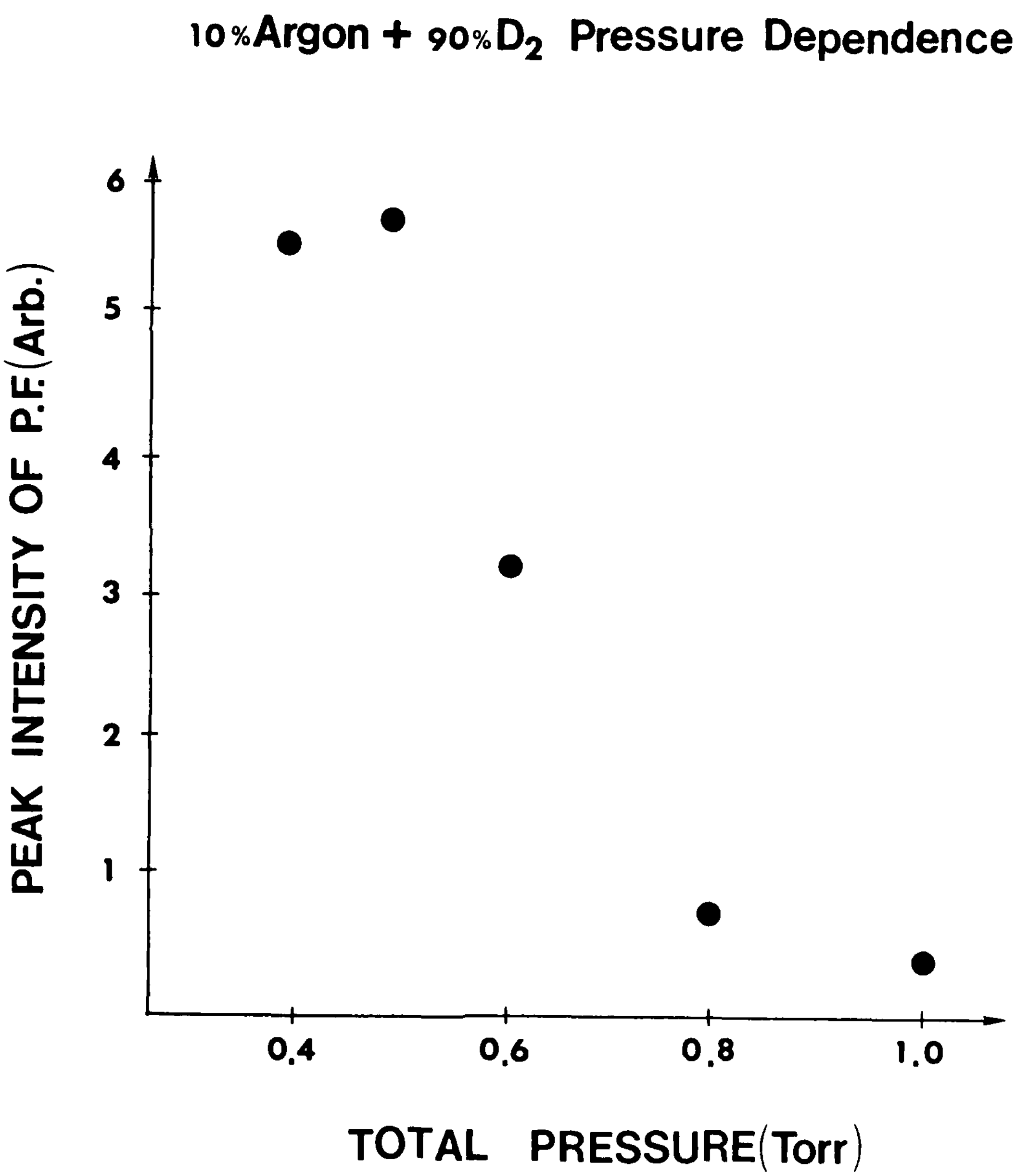


Fig. 11 Peak intensity of the DPF light as a function of total fill gas pressure with 10% Ar and 90% D_2.

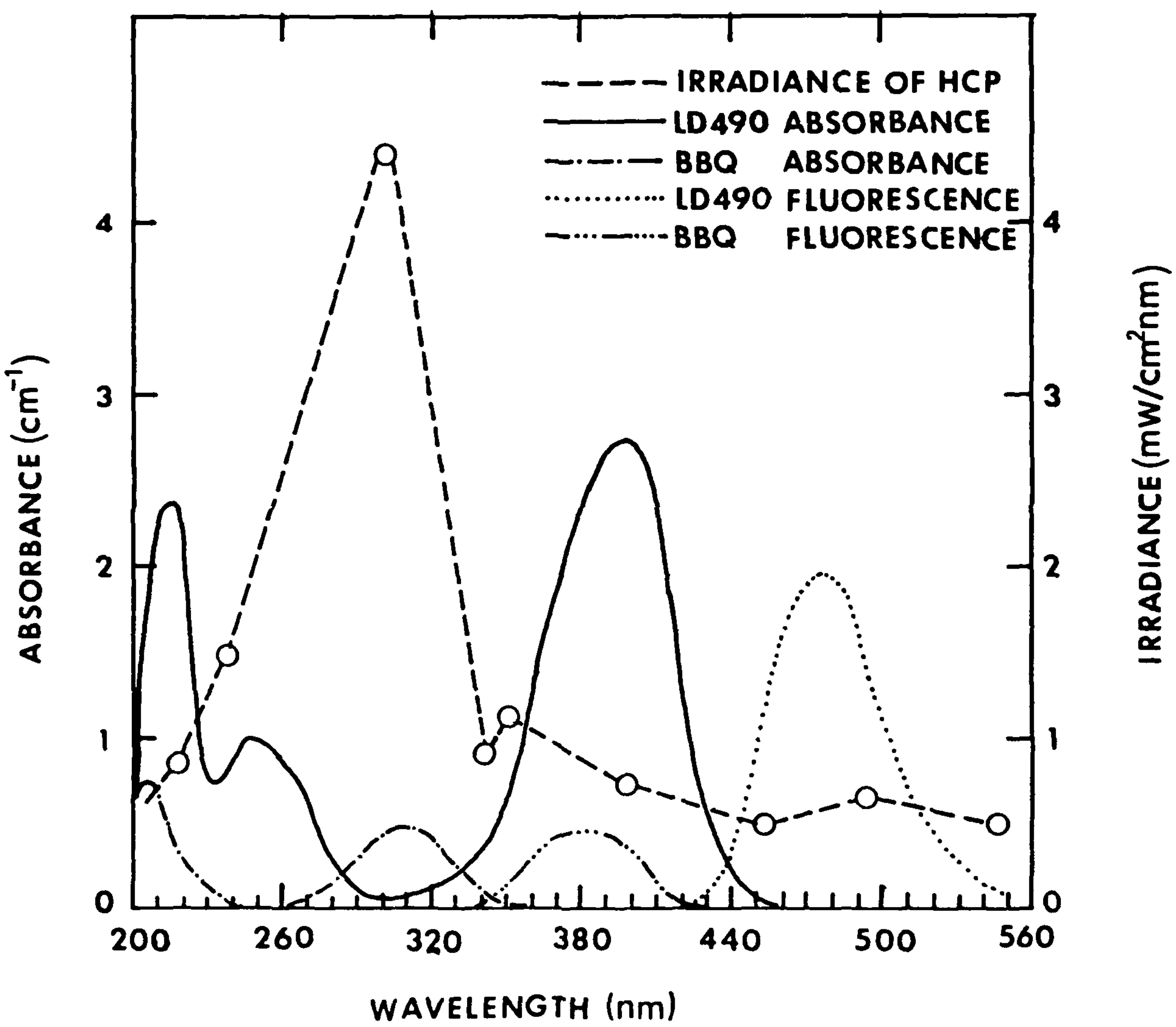


Fig. 12. Absorption curves of dyes and spectrum of HCP pumping source.

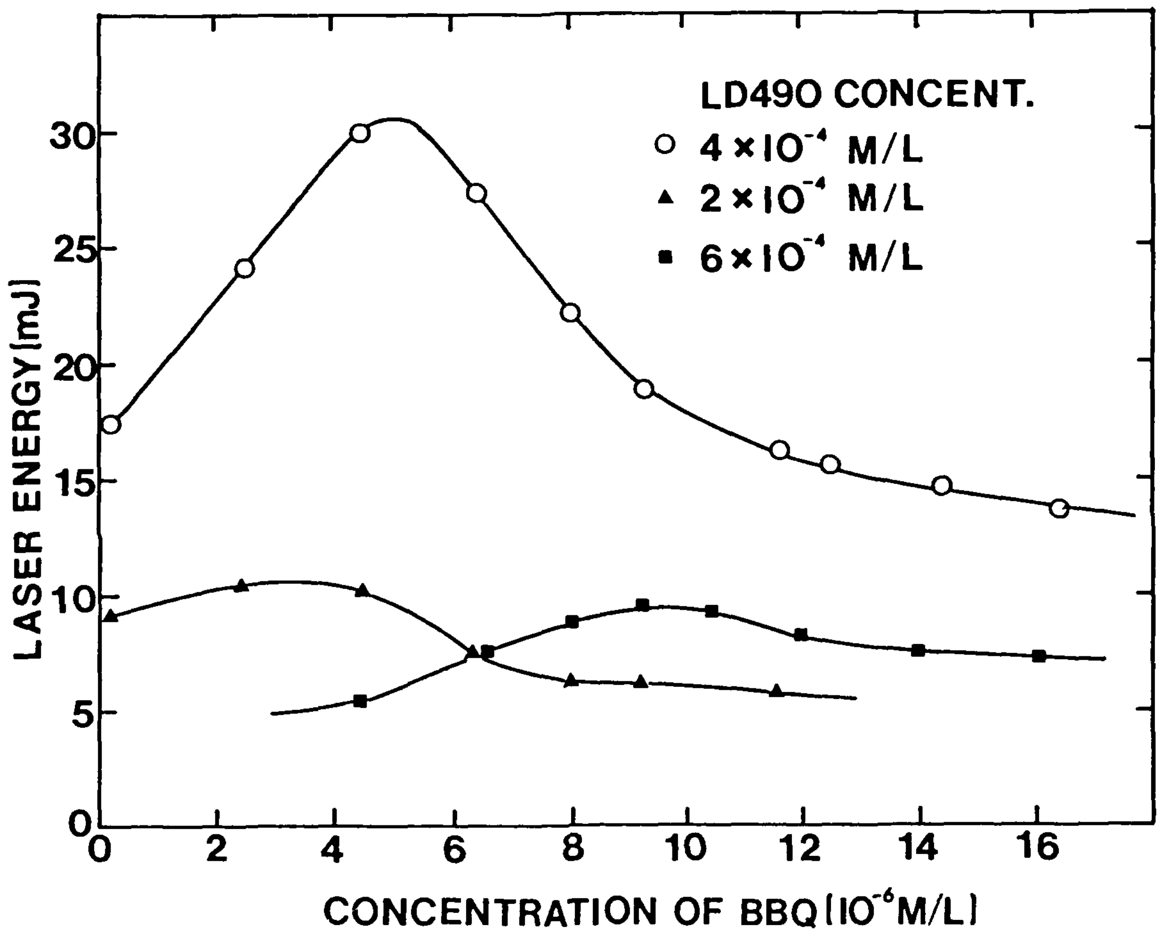


Fig. 13 Laser output of LD490 dye as a function of converter dye BBQ concentration.

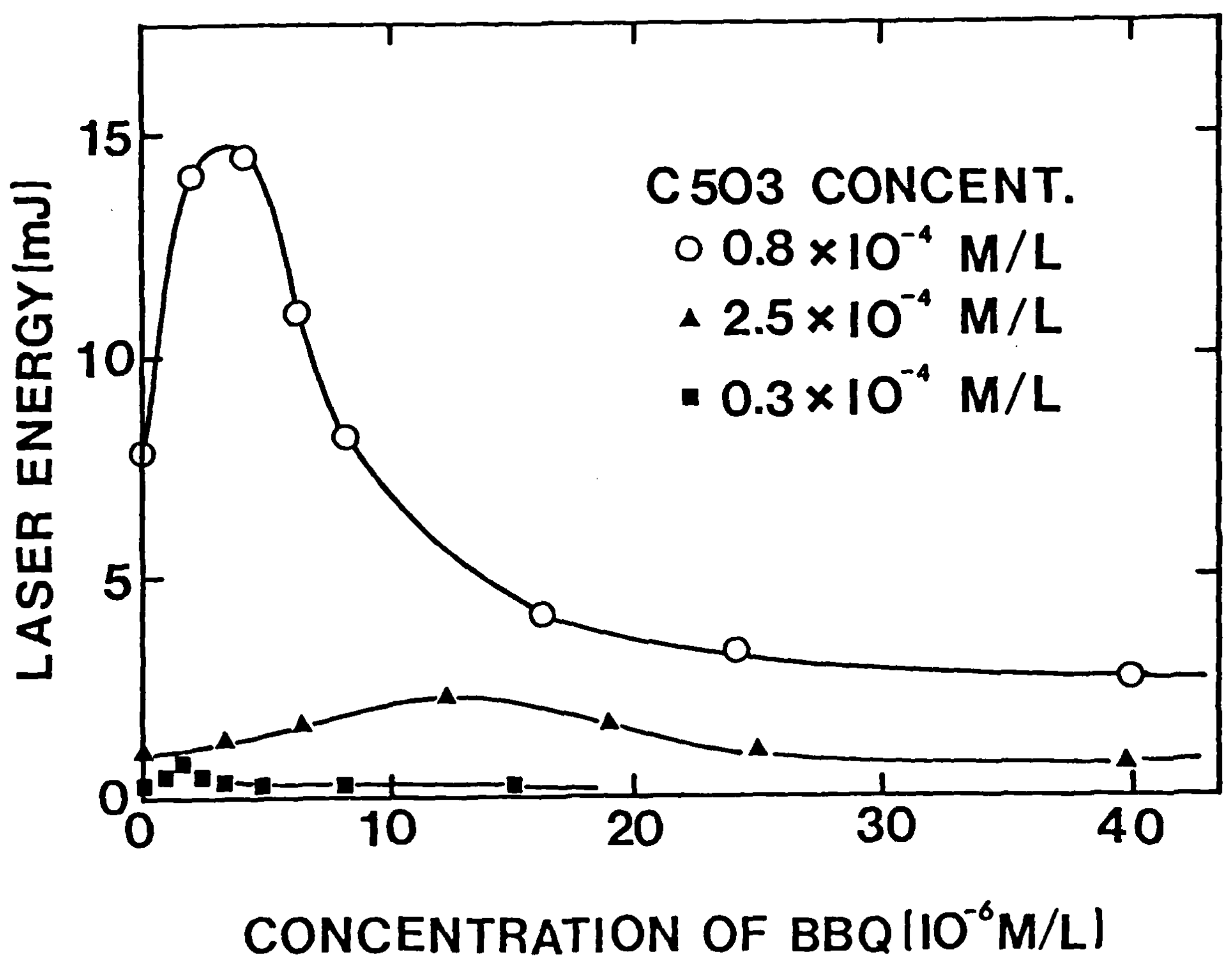


Fig. 14. Laser output of coumarin 503 dye as a function of converter dye BBQ concentration.

VII. List of all Participati .g Scientific Personnel under ARO grnat (DAAG29-85-G-0073) Period Jan 15, 1985-Jan 14, 1986

		Period
K. S. Han	(Principal Investigator)	Jan 15, 1985 - present
J. H. Lee	(Faculty Associate and Adjunct Prof. of Physics)	Jan 15, 1985 - present
C. H. OH	(Research Associate)	June 1, 1985 - Dec 31, 1985
K. D. Song	(Graduate student)	Jan 15, 1985 - present

VIII. List of Publication and Technical Reports generated under ARO grant (DAAG29-85-G-0073) Period Jan 15, 1985- Jan 14, 1986

1. "High Power Blue-Green Laser by Dense Plasma Focus" M. H. Lee, K. S. Han, and J. H. Lee, 1985 IEEE International Conference on Plasma Science Record, IEEE85 CH2199-8 76 (1985)

2. "Enhancemnet of Blue-Green Laser Efficiency by a spectrum converter" K. S. Han, C. H. OH and J. H. Lee, 1985 International Laser Science Conference, AIP Proceeding (1986).

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